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Pavel KLÁTIL***COMPUTER - AIDED ANALYSIS OF ELECTRICAL MEASUREMENTS' ACCURACY****ANALÝZA PŘESNOSTI ELEKTRICKÝCH MĚŘENÍ S PODPOROU POČÍTAČE****Abstract**

In this contribution we (among other things) describe a virtual instrument that is currently being developed and tested in two laboratories at the Department of Electrical Measurements of the VSB - Technical University of Ostrava. The virtual instrument can eliminate some disadvantages of the last part of measuring process when accuracy evaluation is demanded. Determination of the intervals or even uncertainty intervals, in which the intrinsic value of some electrical quantity lies is not always easy matter especially in case of digital multimeters. Some relevant details including the interface of the virtual instrument prototype developed in the framework of scientific and research project (FRVS-1382/2005/F1/a) are also highlighted in this paper. The virtual instrument gives a good opportunity to manipulate up to thirteen simulators of real measuring instruments only by clicking the mouse on corresponding buttons (another meters can be implemented any time later).

Abstrakt

V tomto příspěvku je mimo jiné popsán virtuální přístroj, který je v současné době vyvíjen a testován ve dvou laboratořích Katedry elektrických měření Vysoké školy báňské - Technické univerzity Ostrava. Tento virtuální přístroj může eliminovat některé nevýhody poslední části měřicího procesu, kdy je vyžadováno vyhodnocení přesnosti měření. Určení intervalů nebo dokonce intervalů nejistot, ve kterých leží pravá hodnota elektrické veličiny není vždy snadnou záležitostí, zejména v případě číslicových multimetrů. V příspěvku jsou uvedeny či zdůrazněny některé důležité detaily včetně uživatelského rozhraní prototypu virtuálního přístroje, vyvinutého v rámci vědecko - výzkumného projektu (FRVS-1382/2005/F1/a). Prezentovaný virtuální přístroj umožňuje pracovat až s třinácti simulátory skutečných měřicích přístrojů, a to pouhým kliknutím myši na příslušná tlačítka (do aplikace je možno kdykoliv implementovat další měřicí přístroje).

1 INTRODUCTION

Electro technical or electronic practice frequently requires measurement of electric quantities, such as voltage, current, resistance etc. In many cases we not only read out the measured value from the scale of a meter or multimeter. For example, if the exact results of a measurement are needed, interval in which the intrinsic value of a quantity must be determined too. Determination of the intervals (indication errors or uncertainties) is not always easy matter, mainly in the case of digital multimeters due to relatively large amount of information we need. And what is more, all kind of information we need must be looked up in the corresponding manuals. This and some another facts can bring about wrong measuring results and some subsequent problems such as repetition of whole process, material, financial or other damage and so on, especially when this activity is made by hand (using calculators e.g.) and incompetently.

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2 FUNDAMENTALS OF CONVENTIONAL DIRECT MEASUREMENT

As the electrical quantities are random ones, it is never possible to find out their true values by any means. Besides, there are some other factors that influence the result of a measurement, e.g. the measuring instrument's construction or large number of external conditions, the so called reference conditions such as temperature, humidity, electromagnetic field, frequency etc. Therefore, in addition to the value measured, we are always interested in which tolerance limits the actual value of the measured quantity lies. In other words, we should always find out what the accuracy or error of the performed measurement is, particularly when exact result is sought. The measuring errors are often sorted into following groups:

- method error
- instrument error
- operating error

The method error can be caused in most cases by the assumption of measuring instrument used and in large majority of cases it can be determined as well as corrected because the error sign is always known.

The instrument error arises due to imperfect construction of measuring instruments. The main reason for occurrence of such error can be manufacturing inaccuracy and calibration, destructive forces, internal disturbing magnetic and electric field, aging of the material etc. In contrast to the previous type of error, correction cannot be realized in this case since we do not know the sign of the kind of errors. (Some of the above-cited errors can have partially random character.)

The operating error can be caused when an operator chooses the wrong measuring range, selects the wrong measuring method, does not read the measured value correctly or calculates the tolerance limits incorrectly etc. All such errors typically arise due to failing of the human factor.

To simplify the rather complicated theory of the measuring errors in this paper, we subsequently consider only the above mentioned instrument error and suppose that all reference conditions meet the given tolerances. In that case the indication error of the meter is equal to the instrument error.

In case of analogue instrument, the maximum relative error (the so called accuracy class or just class) must be determined by the manufacturer providing that all reference conditions are met. The accuracy class (AC) is very important characteristic and it is the number from a normalized row that can look like this: 0,05 - 0,1 - 0,2 - 0,5 - 1 - 1,5 - 2,5 - 5. However, in some countries the rows can somewhat diverge from each other. But in spite of that, the accuracy class is always marked out on the meter's scale plate, which is one of the advantages of analogue meters.

If the accuracy class is known, it is then possible to determine the absolute indication error respectively accuracy (both terms are equivalent) of a single measurement (e.g. using only one meter) as follows:

$$\Delta_x = \pm \frac{range}{100} \cdot AC \quad (1)$$

Or, the relative error of the same measurement using the formula

$$\delta_x = \pm \frac{\Delta_x}{X} \cdot 100 [\%] \quad (2)$$

resp. (when substituting the expression in the numerator),

$$\delta_x = \pm AC \cdot \frac{range}{X} [\%], \quad (3)$$

where:

X - the measured value of a quantity X ,
 AC - accuracy class.

In all formulas we must write the signs in front of the fractions, since both absolute and relative indication errors have random character.

From the first formula it is obvious that the absolute indication error is constant on any point of the range. On the other hand, it is not always quite clear that the relative indication error is the hyperbolic or even the equiangular hyperbolic function of the measured value and that the lesser value will be measured, the greater indication error we get. Therefore it is very important to carry out the measurements at least in the second third of the scale.

In case of digital instruments, determination of measuring accuracy or error is slightly more complicated due to some of the following factors:

- accuracy is not defined by a single number
- accuracy is defined for various quantities and ranges by different formulas
- non-uniform notation in the vendors' manuals
- usage of different math expressions in the manuals
- accuracy and other necessary information must be looked up in the manuals

Accuracy of a digital meter is most often stated in the corresponding documentation as the sum of two expressions that represent two types of partial errors of the meter. The first partial error is proportional to the measured value and is usually called "reading error". The second partial error is independent of the measured value and is called "span error".

The accuracy of a quantity X measurement can generally be defined in substantially different ways, e.g., as follows:

$$accuracy_x = \pm A_x = \pm(m\% R + nD) \quad (4)$$

$$accuracy_x = \pm A_x = \pm(m\% \text{ of } rdg + n\% \text{ of } FS) \quad (5)$$

where:

$m\%R$ - $m\%$ of the reading
 nD - n digits (D is the least significant digit on the display)
 rdg - reading
 FS - full scale

There are many other ways of writing the accuracy specifications. That large variability can be a cause of many faults while calculating the measurement result errors, especially when greater number of items obtained with different meters must be calculated.

3 NEW CONCEPT OF MEASURING ACCURACY EVALUATION

Since the eightieths of the last century a new method of accuracy evaluation of measurement has been gradually introduced, based on the crucial term "uncertainty of measurement". Its introduction is based on recommendations of the 70-th and 75-th sessions of the CIPM (International Committee of Weights and Measures) in 1981 and 1985. But a practical manual for users was published not until 1993 by the International Organization for Standardization in Switzerland under the name Guide to the Expression of Uncertainty in Measurement. In the manual it was recommended not to use the classical terms "error of measurement" and "true value" of the measured quantity. The introduction of the evaluation of measurements using

uncertainties instead of errors continues, but the theory of errors and tolerances of measurement as presented above will certainly be used further in the future too.

Uncertainty of measurement is a parameter used with the result of a measurement that characterizes the dispersion of the values that can reasonably be attributed to the measurand. This parameter is actually a standard deviation, resp. a normalized multiple of it. Uncertainty of measurement comprises many components, some of which can be evaluated from the statistical distribution of results of series of measurements and characterized by experimental standard deviations. Other components (which can also be characterized by standard deviation) are evaluated from assumed probability distribution based on experience or other information.

Standard uncertainty is uncertainty of the result of measurement expressed as a standard deviation. It is the basic quantitative characteristic of the uncertainty. The letter "u" (uncertainty) is used as a symbol.

There are two basic types of the standard uncertainty:

- A type (u_A) is found from results of repeated measurements using statistical analysis (its value is decreasing with the increasing number of measurements)
- B type (u_B) is found by other means and its value does not depends on the number of observations

Combined standard uncertainty (u_C) is gained by linking the above cited uncertainties and is equal to the square root of the sum of their squares.

Expanded uncertainties can be obtained by multiplying the above mentioned standard uncertainties by a coverage factor ($cf=2$ or 3).

Supposing that all reference conditions meet the given tolerances and in case of direct measurements (by means of an analogue or digital meter), we can evaluate the standard uncertainties using the following formulas based on statistical principles:

$$u_{Ax} = \hat{\sigma}(\bar{X}) = \sqrt{\frac{1}{n(n-1)} \sum_{i=1}^n (x_i - \bar{x})^2} \quad (6)$$

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad (7)$$

$$u_{Bx} = \frac{\Delta_x}{\sqrt{3}} \quad (8)$$

$$u_{Cx} = \sqrt{u_{Ax}^2 + u_{Bx}^2}, \quad (9)$$

where:

$\hat{\sigma}(\bar{X})$ - the estimate of the standard deviation of repeatedly measured values (sample of values),

\bar{x} - the average value of the sample,

Δ_x - the absolute indication error calculated using the equations (1), (4), (5),

n - the number of the samples.

4 VIRTUAL ANALYZER OF MEASURING ACCURACY

All of the above mentioned problems stemming mainly from the rather complicated theory (especially in case of digital multimeters and calculation of uncertainties) can be eliminated by the virtual instrument VAMA (Virtual Analyzer of Measuring Accuracy), the model of which has been developed in the framework of scientific and research project. The following figures below show some of possible usage of the virtual instrument.

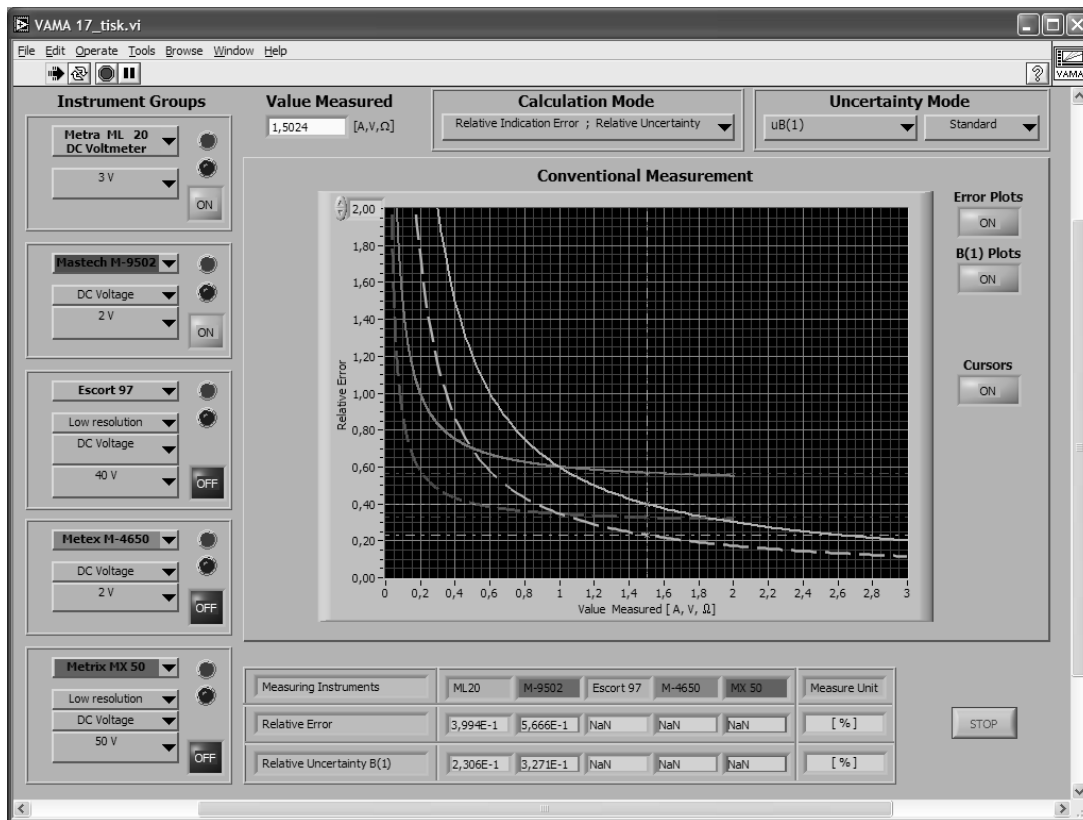


Fig. 1 Example of conventional measurement of voltage and evaluation of its relative accuracy

The virtual instrument gives a good opportunity to manipulate up to thirteen simulators (another meters can be implemented) of real measuring instruments only by clicking the mouse on corresponding buttons. The instrument can be used for a few following activities:

- computation of total indication errors (absolute or relative)
- computation of partial indication errors (absolute or relative)
- computation of all types of uncertainties both in standard and expanded form (absolute or relative)
- display of errors and uncertainties of type B as functions of measured values
- display of statistical functions (average, standard deviation)
- selection the most suitable meter and range before starting measuring process
- learning process

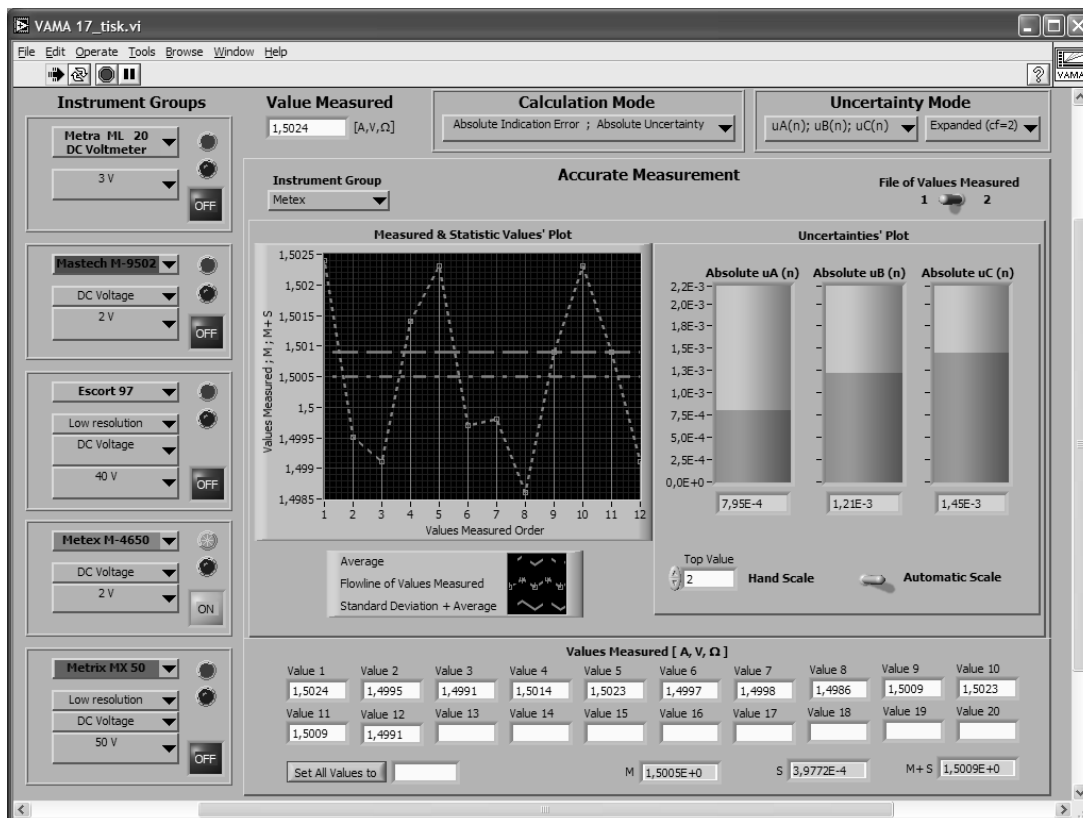


Fig. 2 Example of accurate measurement of voltage and evaluation of its absolute accuracy

5 CONCLUSION

The first part (for conventional measurements) of the above presented virtual instrument VAMA was developed and installed in two laboratories at the Department of Electrical Measurement of the VSB-Technical University of Ostrava in 2004. Since that time it has been permanently and successfully used both by learners and academics in learning process. Therefore it is plausible to predict that this modern tool could assert themselves soon not only in the learning process but also in some industry workplaces.

6 REFERENCES

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